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International Space Station Familiarization

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Foreword

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This material is for training purposes only and should not be used as a source of operational data. All numerical data, displays, and checklist references are intended as examples. To determine any prerequisites before using this document, consult the applicable Certification Plan or Training Catalog.

Two format techniques are used in this document for emphasis. Text which is bolded and italicized is used to emphasize key crew concepts which are crucial to a sections' objective. Gray shaded blocks in the text denote content which is supplemental to a section's objectives.

International Space Station Familiarization

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CONTENTS

Section **Page**

Section **Page**

Section **Page**

Section **Page**

Appendices

Appendix **Page**

TABLES

Table **Page**

FIGURES

Figure **Page**

Figure **Page**

Figure **Page**

Section 1
Introduction to the International Space Station

This section consists of five parts. Parts 1 and 2 cover the overall purpose, objectives, organization, and elements of the International Space Station (ISS). The next three parts address Station operations. Part 3 presents the operations concepts that define crew and controller roles and responsibilities. Part 4 addresses the Traffic Model or when Earth-to-Orbit Vehicles (ETOVs) (e.g., shuttle, Progress, Soyuz, etc.) can rendezvous with the Station. To a large extent the traffic model determines which assembly events can be accomplished within given time frames. Part 5, Life During an Expedition, covers in more detail what happens during and between ETOV visits.

After completing this section, you should be able to

- List the purpose and objectives of the ISS
- Describe the purpose of each major ISS element/module
- Describe the typical operations performed during the major mission activities of ISS

1.1 Purpose, Objectives, and Organization of the ISS

The purpose of the ISS is to provide an “Earth orbiting facility that houses experiment payloads, distributes resource utilities, and supports permanent human habitation for conducting research and science experiments in a microgravity environment.” (ISSA IDR no. 1, Reference Guide, March 29, 1995)

This overall purpose leads directly into the following specific objectives of the ISS program

- Develop a world-class orbiting laboratory for conducting high-value scientific research
- Provide access to microgravity resources as early as possible in the assembly sequence
- Develop ability to live and work in space for extended periods
- Develop effective international cooperation
- Provide a testbed for developing 21st Century technology

To accomplish these objectives, the National Aeronautics and Space Administration (NASA) has joined with four other space agencies and their major contractors. Besides NASA, with its prime contractor Boeing, the ISS Program consists of

- Russian Space Agency (RSA), with its contractors Rocket Space Corporation-Energia (RSC-E) and Khrunichev Space Center (KhSC)
- Canadian Space Agency (CSA), with its contractor Spar Aerospace

- National Space Development Agency of Japan (NASDA), with its contractor Mitsubishi Heavy Industries
- European Space Agency (ESA), with its contractor Deutsche Aerospace

The NASA/Boeing team is further broken down. Besides the Program Office, there are four Product Groups (PGs), each of which has its own responsibilities for specific module or hardware development. These groups and their responsibilities include

- PG 1: McDonnell Douglas - Integrated Truss, Distributed Avionics, Node Integration
- PG 2: Rocketdyne - Solar Arrays, Power Management, and Distribution
- PG 3: Boeing - Habitation (Hab) and Laboratory (Lab) modules, Node structures, Life Support System
- PG 4: Italian Space Agency (ASI) and its contractor, Allenia - Mini-Pressurized Logistics Module (MPLM). (Note: ASI is considered a "contractor" to NASA due to the contractual requirements for MPLM development. Basically, NASA is buying the MPLM from ASI.)

To integrate all these organizations, the following various levels of agreements have been developed

- Government-to-Government agreements, called Inter-Government Agreements (IGAs). These commit the various countries and national space agencies to ISS.
- Agency and Program-level agreements, usually called Memorandums of Understanding (MOUs). These define the roles and responsibilities of the various national space agencies. The most important operational MOU is the Concept of Operations and Utilization (COU). This defines how the Station will be operated and used.
- The COU itself is further developed in the Station Program Implementation Plan (SPIP), which defines how the program will implement the COU. The SPIP has 10 volumes.
  - Vol. I: The high-level statement of the implementation plan
  - Vol. II: Program Planning and Manifesting
  - Vol. III: Cargo Integration
  - Vol. IV: Payload Integration
  - Vol. V: Logistics and Maintenance
  - Vol. VI: Launch Site Processing
  - Vol. VII: Training
  - Vol. VIII: Increment Execution Preparation
  - Vol. IX: Real-Time Operations
  - Vol. X: Sustaining Engineering

Of most interest to the Mission Operations Directorate (MOD) is Vol. IX, which defines how the various partner space agency's control and payload centers will interface and each center's roles and responsibilities. Each partner has development and operational responsibilities for the elements and transportation systems that it provides. NASA is the lead integrator for the program. The control and payload centers are as follows:

- NASA
  - Mission Control Center-Houston (MCC-H)
  - Payload Operations Integration Center (POIC) in Huntsville, Alabama
  - MPLM Technical Support Center in Turin, Italy
- RSA
  - Mission Control Center-Moscow (MCC-M)
- CSA
  - Space Operations Support Center in St. Hubert, Quebec
- NASDA
  - Space Station Integration and Promotion Center in Tsukuba
- ESA
  - Attached Pressurized Module Control Center in Oberfafenhoffen, Germany

Specifically, MCC-H has the overall authority for Station operations for all phases of the program. MCC-M and MCC-H provide vehicle control functions for their respective segments, and each has the capability to back up the other control center for critical functions, if required. Before Flight 5A, MCC-M is responsible for execution leadership. After Flight 5A, MCC-H is responsible for leading the execution of multisegment procedures (procedures that require interfaces or interaction between the U.S. and Russian Orbital Segments (ROSs)) and overall execution leadership. The Mission Management Team, with representatives from each partner, is responsible for program oversight and provides program direction to the real-time execute teams.

All of these IGAs, MOUs, SPIP volumes and control centers are required to support a vehicle that, at Assembly Complete, will be approximately three to four times larger than the present Mir. The ISS will have

- A pressurized volume of 1200 cubic meters
- Mass of 419,000 kilograms
- Maximum power output of 110 kilowatts (kW), with a payload average power allocation of 30 kW
- A structure that measures 108.4 meters (truss length) by 74 meters (modules length)

- An orbital altitude of 370-460 km
- An orbital inclination of 51.6°
- A crew of six (three until Assembly Complete)

Differences Between ISS and Freedom

There are several major differences between the present ISS mission design and the design for Freedom. Most of these differences are driven by the higher beta angles experienced by the ISS. As shown in Figure 1-1, beta angle is defined as the angle between the orbital plane and the ecliptic or vector to the Sun. The maximum beta angle is the orbital inclination plus the Earth's axial tilt (23.5°). Beta angle varies with time of the year and orbital precession effects. So for the ISS with an inclination of 51.6° (driven by the latitude of the Russian launch site), the beta angle varies over the year to maximums of plus and minus 75°. For the Freedom design, with an inclination of 28.5°, the maximum beta angles are plus and minus 52°. The fundamental effect of the beta angle is its influence on percentage sunlight during a given orbit.

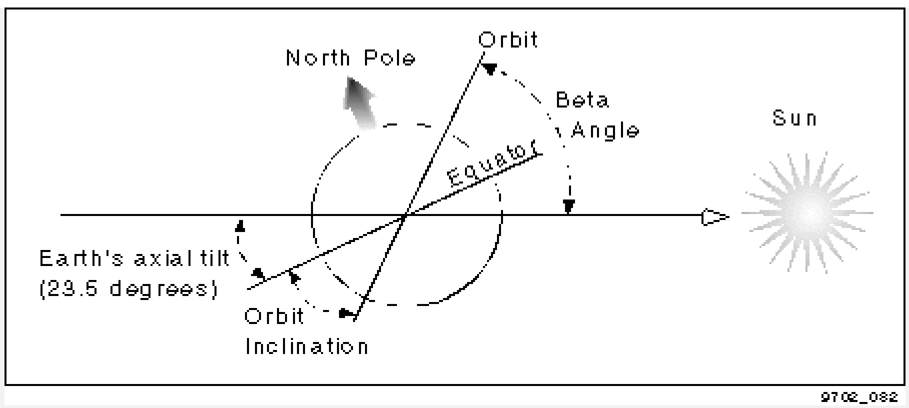

Figure 1-1. Beta angle

Due to equipment design, the ISS will not be able to generate as much power as needed during early assembly during high beta angles. This results from having a beta gimbal, but no alpha gimbal, on the P6 Photovoltaic Array (PVA) when it is mounted on the Z1 truss. (An unfortunate coincidence on the use of the word "beta": the beta gimbal is the gimbal that provides for the rotation of the PVA about the long axis of the array. The other terms (P6, Z1, and alpha gimbal) are explained later.) At high beta angles, the PVA mounted on the Z1 truss with only a beta gimbal cannot be oriented so as to expose it to enough sunlight to meet power generation requirements. Unless the nominal attitude of the Station is changed, lack of adequate power continues to be a problem until Flight 12A, when the PVAs mounted on the truss have both alpha (rotation about the long axis of the truss) and beta gimbals. Instead of flying in an attitude within 15° of Local Vertical/Local Horizontal (LVLH) 0,0,0, (basically an Earth-oriented attitude where the "bottom" of the Station is always facing the Earth), during periods of high beta angles, the ISS has to fly in a quasi-solar inertial attitude called X-Axis Perpendicular to Orbital Plane (XPOP) (or a Sun-oriented attitude where the "top" of the Station is always facing the Sun). In XPOP, the entire Station, and therefore the PVA, will be pointed at the Sun to increase power generation.

When flying at higher beta angles and in the XPOP attitude, the ISS has only half of the original planned communication coverage: down to 15-50 percent U.S. communication coverage and 5-50 percent Russian communication coverage. Also, the thermal conditions on the Station must be closely managed, because the original design did not cover Sun-oriented attitudes, where half the vehicle is in prolonged sunlight and the other half in prolonged shade. Finally, microgravity operations may be affected, because the U.S. attitude control system may not be able to provide the necessary long-term nonpropulsive attitude required.

Building the ISS requires more than 50 flights over a 4.5- to 5-year period. The shuttle flies 31 of the flights. Of these flights, 24 are dedicated to assembly tasks (referred to as the “A” flights; e.g., Flight 5A or the fifth U.S. shuttle assembly flight), and 7 are utilization flights dedicated to bringing up the science experiments (referred to as the “UF” flights; e.g., UF 2). Approximately 11 Soyuz flights will be required to maintain crew escape capability. Most will be used for crew rotation (bringing up a “new” crew and/or returning the “old” crew). Another 10 unmanned Russian assembly flights (generally launched on a Proton and referred to as the “R” flights; e.g., Flight 1R) will be required to bring up the Russian Segment modules. This 50+ number does not include the resupply/logistics flights. Approximately 30 Progress M1 flights are required by Assembly Complete to provide all the logistics. The Progress spacecraft is also used to provide the propulsive force for the reboosts. (A reboost is a posigrade propulsive burn to raise the Station orbit to compensate for orbit altitude decay.)

1.2 ISS Elements

The 50+ flights bring up and assemble the various modules/elements of the ISS. The following paragraphs address the modules/elements in the approximate order that they are assembled (per Assembly Sequence, Rev. C, Sept. 97 update). Figure 1-2 illustrates the ISS at Assembly Complete.

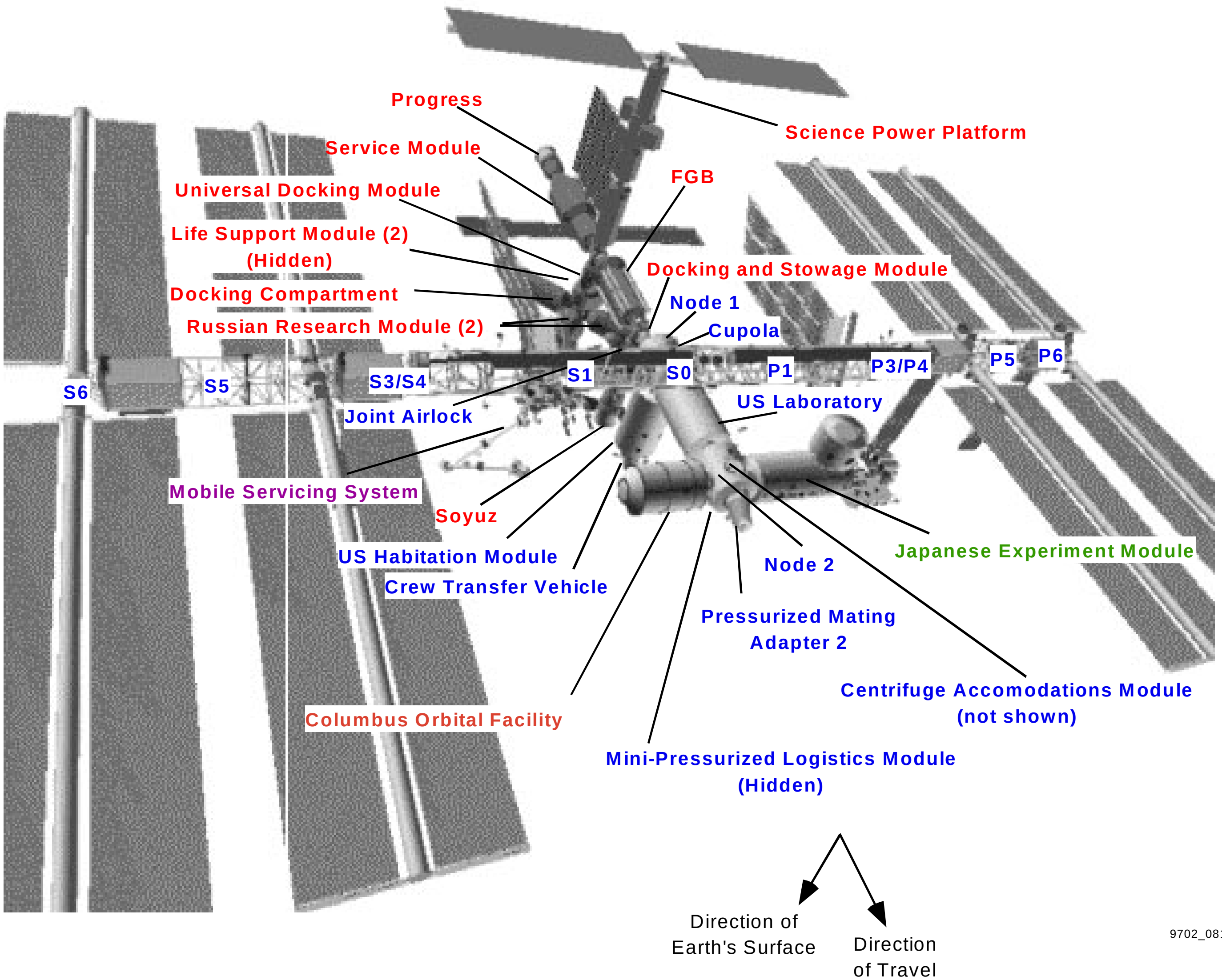

Figure 1-2. International Space Station at assembly complete

1.2.1 Functional Cargo Block

The Functional Cargo Block (FGB) is the first element launched and therefore its launch is often referred to as FEL (First Element Launch). The FGB is built by KhSC and launched and controlled by MCC-M. It is funded, however, by NASA. FGB is a self-contained vehicle capable of independent unmanned orbital operations. The FGB serves as the Station “building block” in that it provides all the critical system functions until the Service Module (SM) is activated. After the SM is activated, the FGB is basically powered down and serves only as a backup and propellant storage tank for the SM. It continues to provide power to the U.S. elements until Flight 4A.

1.2.2 Node

The Node is a U.S. element that provides six docking ports (four radial and two axial) for the attachment of other modules. It also provides external attachment points for the truss. Finally, the Node provides internal storage and pressurized access between modules. There are three Nodes.

1.2.3 Service Module

The SM, similar in layout to the core module of Russia's Mir space station, provides the early Station living quarters, life support system, communication system, electrical power distribution, data processing system, flight control system, and propulsion system. Although many of these systems will be supplemented or replaced by later U.S. Station components, the SM always remains the structural and functional center of the ROS. Living accommodations on the Service Module include personal sleeping quarters for the crew; a toilet and hygiene facilities; a galley with a refrigerator/freezer; and a table for securing meals while eating. Spacewalks using Russian Orlan-M spacesuits can be performed from the SM by using the Transfer Compartment as an airlock.

1.2.4 Soyuz

Besides being an Earth-to-Orbit Vehicle (ETOV) used for crew rotations, Soyuz is the Russian element that provides the crew emergency return (“lifeboat”) capability, at least through Assembly Complete. As such, there is always a Soyuz docked to the Station whenever the Station crew is onboard. Therefore, launch of the Soyuz marks the beginning of permanent human presence of a three-person crew. At least every 6 months, the docked Soyuz is replaced with a “fresh” Soyuz. After Assembly Complete, the Soyuz may be replaced by the Crew Rescue Vehicle (CRV).

1.2.5 Laboratory

The Lab is a U.S. element that provides equipment for research and technology development. It also houses all the necessary systems to support a laboratory environment and control the U.S. Segment.

1.2.6 Mini-Pressurized Logistics Module (hidden in Figure 1-2)

Because the Mini-Pressurized Logistics Module (MPLM) is provided by ASI under contract to NASA, it is considered a U.S. element. It allows transfer of pressurized cargo and payloads. It is launched on the shuttle and berthed to the Node, where supplies are offloaded and finished experiments are loaded. The MPLM is then reberthed in the shuttle for return to Earth. The MPLM will be used numerous times during the lifetime of the Station.

1.2.7 Joint Airlock

The Joint Airlock is a U.S. element that provides Station-based Extravehicular Activity (EVA) capability using either a U.S. Extravehicular Mobility Unit (EMU) or Russian Orlon EVA suits.

1.2.8 Interim Control Module (not pictured)

The Interim Control Module (ICM) is a U.S. module built by the Naval Research Laboratory capable of providing the guidance, navigation, control, and propulsion functions for the ISS. Whether the ICM is used and what exact functions it provides is dependent on the timing and capabilities of the SM. The ICM is not planned to be a permanent feature of the ISS.

1.2.9 Docking Compartment

There are two Russian element Docking Compartments (DCs) to provide egress/ingress capability for Russian-based EVAs and additional docking ports.

1.2.10 Truss

Built over numerous flights, the truss is a U.S. element that provides the ISS “backbone” and attachment points for modules, payloads, and systems equipment. It also houses umbilicals, radiators, external payloads, and batteries. The truss is based on the Freedom pre-integrated truss design. The truss segments are labeled by whether they are on the starboard (right) or port (left) side of the Station and its location. An example is the P6 truss is located on the outermost port side. Two exceptions to this labeling scheme are truss S0, which is actually the center truss segment, and during early assembly, the P6 truss segment, with its PVA, is actually mounted on the Z1 truss on the Lab. The Z1 truss itself is an anomaly in that it is not part of the main truss but a truss segment needed under the ISS design until the main truss is built.

1.2.11 Science Power Platform

The Science Power Platform (SPP) is a Russian element that is brought up by the shuttle to provide additional power and roll axis attitude control capability.

1.2.12 Universal Docking Module

The Universal Docking Module (UDM) is a Russian element that provides a five-port docking node for additional Russian modules and vehicles. It performs the same function as the U.S. Nodes.

1.2.13 Japanese Experiment Module

The JEM is a Japanese element that provides laboratory facilities for Japanese material processing and life science research. It also contains an external platform, airlock, and robotic manipulator for in-space ("exposed") experiments and a separate logistics module to transport JEM experiments.

1.2.14 Docking and Stowage Module

The Docking and Stowage Module (DSM) is a Russian element that provides facilities for stowage and additional docking ports. There are two DSMs.

1.2.15 Cupola

The Cupola is a U.S. element that provides direct viewing for robotic operations and shuttle payload bay viewing.

1.2.16 Research Module

The Research Module (RM) is a Russian element that provides facilities for the Russian experiments and research. It is analogous to the U.S. Lab. There are two RMs.

1.2.17 Columbus Orbital Facility, Also Known as the Attached Pressurized Module

The Columbus Orbital Facility (COF) is an ESA element that provides facilities for the ESA experiments and research. It is analogous to the U.S. Lab.

1.2.18 Life Support Module

The Life Support Module (LSM) is a Russian element that provides additional crew equipment and air revitalization capability.

1.2.19 Crew Rescue Vehicle, Also Known as the Crew Transfer Vehicle

Similar to the Soyuz, the CRV provides the emergency crew return ("lifeboat") function. Although the exact design is still TBD, it will be based on NASA's X-38. The X-38 will have a six-person return capability, and therefore its presence (or the presence of a second Soyuz) is a requirement for going to a six-person crew. The X-38 will have a fully automated deorbit/landing mode, although the crew can manually override landing site selections.

1.2.20 Centrifuge Accommodations Module (not shown)

The Centrifuge Accommodation Module (CAM) is a U.S. element that provides centrifuge facilities for science and research. It also houses additional payload racks.

1.2.21 Habitation Module

The Hab is a U.S. element that provides six-person habitation facilities, such as personal hygiene (better waste management, full body shower), crew health care, and galley facilities (wardroom with eating facilities, oven, drink dispenser, freezer/refrigerator).

1.2.22 Logistics Vehicles

Logistics flights are required throughout the life of the ISS and will be accomplished using a variety of vehicles. The shuttle will be used to bring water, and pressurized cargo. When the Mini-Pressurized Logistics Module (MPLM) is used, the shuttle can bring nearly 9 metric tons of pressurized cargo to ISS. The shuttle is also the only means for returning items intact from ISS.

The Progress M1 is provided by RSA and used to accomplish three primary tasks: orbital reboost, attitude control fuel resupply, and pressurized cargo resupply. It will be launched on a Soyuz booster. Fuel that is not required for a reboost is transferred to the FGB and SM tanks to be used for propulsive attitude control. Pressurized cargo includes oxygen, nitrogen, food, clothing, personal articles, and water. The Progress is filled with trash as its stores are consumed, and when exhausted, undocks, deorbits, and re-enters the atmosphere over the Pacific Ocean.

The Autonomous Transfer Vehicle (ATV) is provided by ESA and is scheduled to be completed in 2003. It will be launched on an Ariane V launch vehicle. It is roughly three times as large as the Progress M1, but is functionally the same as described above.

The H-2 Transfer Vehicle (HTV) is provided by NASDA and is scheduled to be completed in 2002. It will be launched on a H-2A launch vehicle. Its purpose is to carry pressurized cargo only. Unlike the Progress M1 and ATV, the HTV doesn’t carry resupply fuel, and it doesn’t dock. It rendezvous to the forward end of the Station and is grappled by a robotic arm and berthed.

1.3 Operations Concepts

The overriding principle of Station operations is that the ISS will operate as an integrated vehicle with an integrated crew and a single crew commander. This means that all crewmembers perform a common set of tasks and have a common knowledge base of the entire Station. To ensure that integration, English is defined as the language of operations. Therefore, all important operations discussions, either between crewmembers or between crew and ground, are conducted in English. This ensures that all parties understand what is being discussed, its impacts, and any decisions made. Another concept to further crew integration is that a crew rotation involve the entire crew of three (no partial crew rotations). This way the crew trains together, launches together, works together, and returns together. The Multilateral/ Bilateral Crew Operations Panel is the primary forum for top-level coordination and resolution of Station crew matters. Of the 51 flight opportunities through Assembly Complete, 25 are currently allocated to RSA, 25 to NASA, and 1 to NASDA.

The control centers MCC-M and MCC-H (a.k.a. “ground”) are mainly responsible for core system planning and operations, while the crew is mainly responsible for payloads, EVA, and robotic operations. Although the ground is “prime” for system operations, limited communication coverage requires that the crew be trained for routine core operations, have the capability to review all Caution and Warning messages, and respond to time-critical anomalies from anywhere in the Station. This means that the crew must have access to most of the vehicle commands. This is presently a technical challenge, since the crew currently does not have a single command and data interface for the entire vehicle.

Although one integrated plan is used by the onboard crew to ensure safety and prevent payloads from interfering with each other, each partner has mission planning responsibilities for the payloads, elements, and transportation vehicles that it provides. The Execute Planning Control Board is responsible for overall integration.

Each partner is also responsible for training the crew on their segment, with the International Training Control Board performing the training integration. Training can be broken into four phases, as shown in Table 1-1

Table 1-1. Training phases

Phase	Emphasis	Duration
Basic	Vehicle familiarization, science background, operations overviews, survival training, and cross-cultural training	Approximately 1 year
Advanced (training as a member of a group)	Generic training of Station systems and payloads, malfunction procedures, habitation, and Soyuz contingency return training	Approximately 1 year
Increment-Specific (training as a member of a crew)	Mission-specific training for EVA, robotics, activation/ checkout and payloads, multisegment and team training	Approximately 1.5 years
Onboard (Board)	Handover training, proficiency and just-in-time training accomplished as needed on orbit.	

1.4 Traffic Model

The traffic model determines what ETOV arrives when. The traffic model is driven by three interrelated items: the assembly sequence, the altitude strategy, and crew rotation. The assembly sequence determines the next piece of hardware to be added to the Station, either shuttle-berthed modules or unmanned Russian docked modules, and its delivery method. When the designers know the Station hardware to be delivered, specifically its weight and center-of-gravity and the delivery method, they can determine the maximum Station altitude for a successful rendezvous. With any higher altitude, the ETOV does not have sufficient capability to reach that altitude.

Launcher capability, both U.S. and Russian, is a major constraint on the assembly sequence planning. This plays into the altitude strategy.

Besides determining the Station's altitude for rendezvous, the designers must also consider certain factors so that a missed propellant resupply/reboost (referred to as a "skip cycle") will not result in a dangerously low orbit. These factors include equipment design limits, microgravity requirements, orbital decay due to atmospheric drag and solar flux, and having enough "pad" in the propellant onboard and/or orbital altitude. In case of a skip cycle, the Station can reboost itself using FGB/SM propellant and the SM jets. If the orbit is high enough, the Station can stay in the present orbit and wait for the next Progress. All of these factors and many more result in an orbit planned as high as possible to meet microgravity requirements. The orbit is bounded on the "high" end by equipment design limits and the ability of the ETOVs to reach the Station; it is bounded on the "low" end by the requirement that the Station must be able to miss a propellant resupply/reboost mission and still be above a defined safe minimum altitude by the next resupply/reboost mission.

A further complication is crew rotation, defined as bringing up a new crew and returning the old crew. How often crews are rotated is governed by several factors: crew health, ETOV capability, efficient use of resources, etc. Since long-duration spaceflight takes a physical, mental, and emotional toll on the crew, crew health is one of the factors that determine how long a crew stays on orbit. Another factor that determines length of crew stay on orbit is "training resources." The longer a crew stays on orbit, the more assembly tasks they are required to perform and, therefore, the more training they must receive. There are limits on the amount of training that the crew and training facilities can support. While crew health and crew training are two factors that limit a crew's maximum stay, ETOV capability and efficient use of resources limit a crew's minimum stay. Crews are rotated on either the shuttle or the Soyuz. When crews are rotated on the shuttle, they take away capability of the shuttle to bring up hardware; cargo must be taken off to compensate for the weight of the crew and their equipment. Remember, ETOV launcher capability is a major constraint to the assembly sequence, therefore, the more crew rotations done on the shuttle, the more shuttle flights required to launch the U.S. elements. Launching crews on the Soyuz instead of the shuttle is not a solution. First there are only a limited number of Soyuz vehicles. Additionally, when the Soyuz is used for a three-person crew rotation (it is always preferred to rotate the entire crew at the same time), the Station crew is also the Soyuz crew and therefore must be trained for Soyuz ascent tasks (they must always be trained for entry tasks, because they may need to make an emergency entry at any time, even if the shuttle is their planned entry vehicle). This significantly increases their training time. Therefore, efficient use of the ETOVs determines the minimum crew stay. This discussion provides merely an illustration of how three factors influence crew rotations and should not be considered an exhaustive review.

The assembly sequence, altitude strategy, and crew rotation results in a traffic model. A traffic model shows what ETOVs arrive at the Station and when. Looking at the Figure 1-3, the crew arrives on a Soyuz (Flight 2R), followed by a Progress resupply flight (Flight 2P). Besides resupply, Progress also reboosts the Station to a higher altitude. How high the Station is reboosted depends on two things: low enough that the Station's orbit will decay to the right altitude for the shuttle Flight 4A rendezvous but high enough in case the next Progress flight

(Flight 3P) is missed. Approximately 5 ½ weeks after the reboost, shuttle Flight 4A docks with the Station. There is no crew rotation on 4A, so the entire shuttle uplift capability can be devoted to bringing up new Station hardware. Progress Flight 3P is a resupply/reboost mission. Shuttle Flight 5A is very similar to Flight 4A. A crew rotation occurs on Flight 6A, which means that there had to be enough weight and performance margin to bring up Station hardware and three new crewmembers. Note that the crew will be on-orbit for 156 days. Although not long compared to cosmonaut stays on Mir, the stay will be only 1 month short of Shannon Lucid's record breaking stay in space for an American.

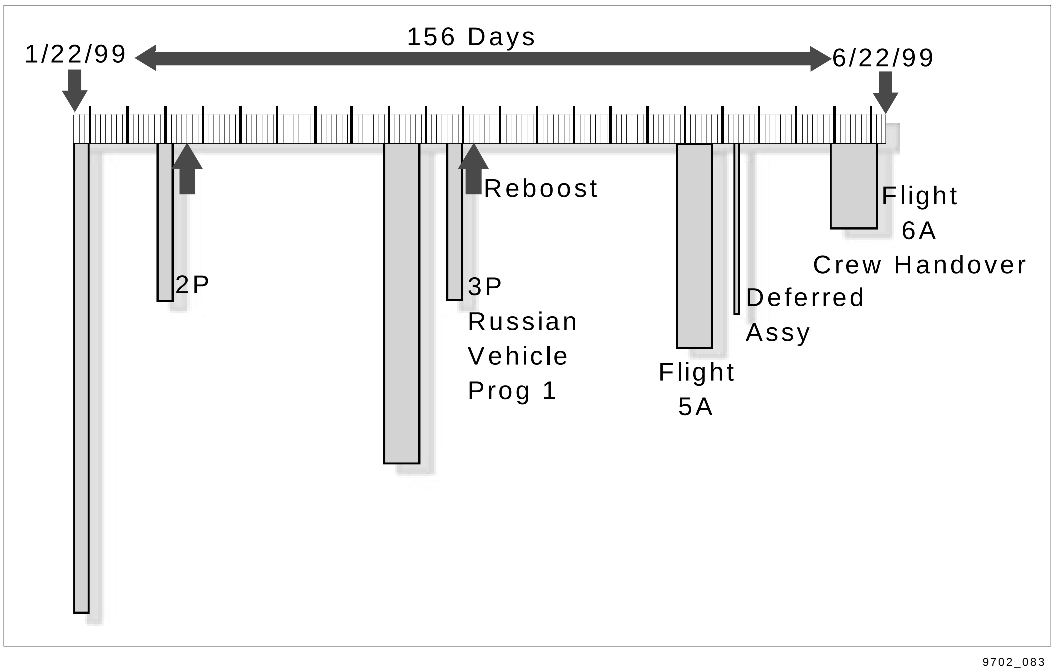

Figure 1-3. Expedition 1 (ABC)

In the Figure 1-3 the event labeled "Deferred Assy," stands for Deferred Assembly tasks. To reduce the number of assembly tasks that the Station crewmembers must perform and, therefore, reduce their training time, it is usually preferable for the shuttle crew to do as many of the assembly tasks as possible. However, there are times when there are too many tasks to be performed in the short time that the shuttle is docked to the Station. Therefore, certain tasks are "deferred" until after the shuttle has departed, and those tasks will be done by the Station crew. Additional information is included in the next section.

1.5 Life During an Expedition

While previous paragraphs explained the Expedition 1 traffic model, the events in a simplified traffic model include the following

- Progress docking
- Reboost

- Quiescent operation
- Shuttle docking/mated operations
- Crew handover
- Deferred assembly

1.5.1 Progress Docking

The key operations concept in any Russian vehicle docking is that the docking must be accomplished over Russian communication sites. (MCC-M must have command and control capability.) The actual docking is automated with little or no crew action required, but the Station crew can fly the vehicle remotely from the SM, if required. The basic sequence of events requires the PVAs to be “feathered” (oriented parallel to the velocity vector of the docking vehicle) to prevent them from being “plumed” by the jets of the Progress. Because the arrays are feathered, they are not able to track the Sun and, therefore, are not able to generate normal power outputs. During this period of lower power output, nonessential Station operations, like payloads operations, are suspended, and the vehicle is powered down. The Station is then maneuvered to docking attitude. All these actions happen several hours before docking. During a period of MCC-M ground coverage, the Progress does a fly-around, acquires the Kurs radar system, and is commanded to dock. After docking, the Station is then maneuvered to its nominal attitude and the arrays resume Sun tracking. With full power being generated, all systems are powered up approximately 1 hour after docking. Checkout and unloading of the Progress takes about 1 week of heavy activity. The vehicle typically remains docked until just before the arrival of the next Progress.

Instead of a Progress, the Russian vehicle could be a module such as the RM. The RM would come up as an independent spacecraft (versus being brought up in the payload bay of the shuttle) with an attached Universal Instrumentation System (UIS) delivering the module to the Station for docking to the UDM. Once docked, it usually takes 1 week and potential EVAs to activate and checkout the new module. During this activation, some tasks could require major system reconfigurations, involving the interruption of data and/or power. Also, when busy with assembly tasks, the crew may not be available for payload operations.

1.5.2 Reboost

Besides being a resupply vehicle, the Progress is also the primary method to reboost the Station. The key operations concept in a reboost is that the ground is heavily involved. The Trajectory Operations Officer (TOPO) at MCC-H plans the reboost and MCC-M actually executes it. At least for the early Progress reboosts, the crew has little insight and no command capability to either start or stop the reboost. The basic sequence of events requires that the Station be transitioned to the reboost software mode and then maneuvered to the reboost attitude. Attitude control is very important, since the reboost is an open-loop burn (a burn in a predetermined attitude for a fixed time without active guidance). At the appropriate time, MCC-M commands the jets to fire for a specific length of time. During the burn, certain system inhibits (e.g., water dump inhibits) are in place, but powerdowns are not expected. Payload operations requiring microgravity will be suspended. Reboosts usually take two burns. At the end of the second burn, the Station is maneuvered to its nominal attitude, and the software is transitioned to its standard software mode. The vehicle is ready to spend the next several weeks or months in quiescent operations.

1.5.3 Quiescent Operations

Quiescent operations refers to the “quiet period” after reboost when the Station is not being visited by ETOVs and, therefore, microgravity operations can be maintained for long periods of time. At Assembly Complete, there is a requirement that there be 180 days per year of microgravity operations occurring in increments of a least 30 days. Although there are no requirements on the length of time that microgravity operations are achieved during assembly, planning attempts to maximize microgravity periods. This is the period when the majority of payload operations are accomplished, and when the crew can expect a “nominal work week” of 44 hours. On days 1-5 this results in 8 hours per day of work activity plus 2 hours of exercise and 30 minutes of planning. Besides payload operations, these work days also involve any deferred assembly, maintenance, and routine system operations. Four hours of housekeeping occur sometime over days 6 and 7.

1.5.4 Shuttle Docking/Mated Operations

While a shuttle docking is not significantly different than a Progress docking, one difference is that there is a data interface between the shuttle and Station. This means that the shuttle crew has insight into ISS status and can command the ISS. Once mated, assembly tasks can be started. Shuttle crews are usually “prime” for the majority of the assembly work. This lessens the training requirements for the Station crew and allows the most current and therefore proficient crew to perform the task. One reason that the Station crew would be “prime” is if the shuttle crew was unavailable. An example may be multiple EVAs. For the shuttle crew to do two EVAs, there must be a day off between the two EVAs. If the schedule does not allow for the day off, the Station crew may have to do the EVA. (Another option is to have two shuttle EVA teams, with Team 1 doing the first EVA and Team 2 doing the second EVA). If not involved in assembly tasks, the Station crew will be busy with transfer tasks, transferring the logistics from the shuttle and/or MPLM into the Station, and finished experiments and other items to be returned to Earth into the shuttle/MPLM. Prior to 7A, all U.S. assembly EVAs are shuttle based (the Joint Airlock is brought up on 7A). Shuttle-based EVAs are done by the shuttle crew and require the shuttle crew to stay in the shuttle almost exclusively. Much of the assembly use the shuttle robotic arm. After 7A, most assembly takes place in the Station with little orbiter involvement. This means that the shuttle crew will be in the Station doing EVAs using the Joint Airlock and operating the Station robotic arm. Typical mated operations would involve 6-9 days docked, three EVAs, two major robotics operations, and system and/or payload activation. During this activation, some tasks could require major system reconfigurations, involving the interruption of data and/or power. Actual payloads operations would be minimal, due to Station and shuttle crew workload.

1.5.5 Crew Handover

On flights that have a crew rotation, the arriving and departing Station crews must "handover" to ensure a smooth transition. The handover actually starts before launch of the shuttle. For several weeks before launch, the two crews have been talking on videocons as the on-orbit crew has been explaining anything that might be different from what they encountered in training, any Station anomalies, any techniques that they developed, and anything else that they believe eases the transition of the new crew. Once docked, the overlap in two crews lasts 1-7 days. The arriving crew receives safety briefings and participates in some safety exercises. They are also briefed on vehicle changes and payload operations. Crews also have to exchange Soyuz seat liners and associated equipment.

1.5.6 Deferred Assembly

Once the shuttle has undocked, deferred assembly tasks can be accomplished. One key operations concept is that deferred assembly tasks are usually not time critical. Since we are not constrained to accomplish the tasks within the 6-9 days that the shuttle is docked, the exact timing for accomplishing the task is very flexible. Tasks are fit in to the overall schedule as time allows. Deferred assembly tasks should also not contain time critical procedures. This means that the task cannot require that the entire procedure be done in x hours or something bad will happen; e.g., the payload freezes if the procedure is not finished within 3 hours. Deferred tasks usually assume that the crew has been on orbit for several weeks or even months and therefore is not current and/or proficient enough to be able to accomplish this type of time-critical activity. Due to this relaxed timeline, the crew is given time to review procedures and systems knowledge before the event. An example of this relaxed timeline is, although EVAs could be scheduled as close as every other day, deferred EVAs are usually scheduled every 3-4 days. As in any assembly task, some tasks could require major system reconfigurations involving the interruption of data and/or power. Also, when busy with assembly tasks, the crew may not be available for payload operations. Finally, EVAs and robotics operations affect microgravity operations, so although deferred EVAs may be accomplished during the period normally associated with quiescent operations, microgravity experiments may be affected.

1.6 Summary

The purpose of the ISS is to provide an Earth orbiting facility with the resources to conduct microgravity research. The objectives of the ISS program are to provide access to a world-class microgravity laboratory as soon and as easily as possible, to develop the ability for long-duration spaceflight, to develop effective international cooperation, and to provide a testbed for 21st Century technology.

The name and purpose of each major element/module follows

- Hab and Service Module (SM) provide living facilities.
- Lab, Research Modules (RMs), Japanese Experiment Module (JEM), Columbus Orbital Facility (COF), and Centrifuge Accommodations Module (CAM) provide research facilities.

- Nodes, DSMs, Docking Compartments (DCs), and Universal Docking Module (UDM) provide docking ports for the attachment of other modules.
- Soyuz and CRV: provide emergency crew return capability.

The major events on the ISS are ETOV docking, reboost, quiescent operations, crew handover, and deferred assembly. During any of these events, the ISS is considered an integrated vehicle with an integrated crew and a single commander. The normal delegation of assignments has the ground responsible for system operations and the crew responsible for EVAs, robotics, and payload operations. Although each mission control is responsible for control of activities on their segment and MCC-H has overall integration responsibility, the crew has the capability to control all the major functions on the ISS.